◆ Outline

- **What are the goals?**
- **Where are we now?**
- **What are the hadron collider options?**
- **How do we choose among options?**
- **What is the best R&D strategy?**

◆ *What are the goals?*

- ***Determine if there are physics questions that require higher energy hadron colliders.***
- ***Design working, reliable, affordable colliders of the right energy and luminosity to answer those questions.***
- ***Execute a vigorous R&D program to develop the technical and civil construction components of the collider.***
- ***Put the politics, collaborations and public relations into place that will make it possible to build and operate the collider.***

◆ Where are we now?

- The Tevatron is the world's highest energy machine, and has great frontier physics for the next 8–10 years.
- The LHC is being built at CERN. The U.S. is participating in the machine and the detectors.
- The world HEP community is searching for the right thing to do as the next step after the LHC.
- The U.S. HEP community is starting to organize and plan for the vlhc. A national vlhc organization has been created.
- A vigorous R&D program in both high-field and low-field vlhc magnets is starting at Fermilab.

◆ A National vlhc Organization

● There is a national vlhc organization.

- **At the initiative of John Peoples, representatives of BNL, Fermilab, LBNL met at Fermilab in February to discuss the form of a vlhc R&D organization in response to the Gilman Subpanel recommendation:**

"The Subpanel recommends an expanded program of R&D on cost reduction strategies, enabling technologies, and accelerator physics issues for a vlhc. These efforts should be coordinated across laboratory and university groups with the aim of identifying design concepts for an economically and technically viable facility."

- **Peoples asked the Directors of the BNL, LBNL and Cornell to appoint members of a Steering Committee.**

BNL members:	**Mike Harrison, Stephen Peggs**
Cornell Member:	**Gerry Dugan**
Fermilab Members:	**Peter Limon, Ernie Malamud**
LBNL Members:	**Bill Barletta, Jim Siegrist**

◆ A National vlhc Organization

- **First meeting of the *Steering committee for a future very large hadron collider.***

  April 24, 1998 at Fermilab.

  - **The Steering Committee membership will initially be small.**
  - **The working groups will be open to all and participation is welcomed from all US and foreign institutions.**
  - **Initially, the site of vlhc is assumed to be Fermilab.**
  - **Focus on the technology and cost reduction for vlhc accelerators.**

- **Working Groups and convenors:**

  Accelerator physics: **Alan Jackson, Shekhar Mishra, Mike Syphers**
  Magnet technologies: **Bill Foster, Ron Scanlan, Peter Wanderer**
  Accelerator technologies: **Don Hartill (maybe), Chris Leeman, John Marriner**

  - **Next meeting: July 25, Brookhaven**
    Reports from Working group convenors on progress toward signing on volunteers and organizing workshops.

f vlhc R&D at Fermilab

- **General meeting for all participants around March, 1999**
  Reports from workshops, generation of Annual Report

◆ A National vlhc Organization

● Charge to the Steering Committee

The *Steering Committee for a future very large hadron collider* has been established to coordinate the U.S. effort towards a future, post-LHC, large hadron collider. Its initial membership consists of representatives appointed by the Directors of BNL, FNAL, LBL, and Cornell University's Laboratory of Nuclear Studies. The *Steering Committee* does not manage the work of the individual institutions. It fosters communications between groups, defines parameters, encourages joint work, and seeks to avoid duplication of resources. The *Steering Committee* appoints working groups to deal with specialized issues. The Steering Committee will organize the selection of a good name and logo for the vlhc. It will issue an annual report summarizing work of each group and setting goals for the next year. The *Steering Committee* will encourage the exchange of personnel between participating institutions, promote coordination in planning and sharing of research facilities and provide a mechanism for all interested parties to participate in the evaluation of the alternative technological approaches that are presently being pursued.

A National vlhc Organization

Mission statement

The *Steering committee for a future very large hadron collider* coordinates efforts in the United States to achieve a superconducting proton-proton collider with approximately 100 TeV cm and approximately 10^{34} $cm^{-2}sec^{-1}$ luminosity.

General charge to the working groups

Guided by the Snowmass-1996 parameter sets explore and develop innovative concepts that will result in significant cost reductions. Coordinate parameter sets and infrastructure requirements for the various options and designs with the other working groups.

◆ A National vlhc Organization

● Specific charges to the working groups

Accelerator Physics Working Group

(includes parameters, dynamics, aperture and relaxation of tolerances, cooling (bunched beam, optical stochastic, electron)).

Explore the viability of the various parameters sets implied by the major magnet options.

Magnet Technologies Working Group

(includes materials and may include cryogenics, vacuum).

Review progress in magnet R&D. Develop bases including costs for comparing different magnet designs. Monitor, encourage and coordinate progress in materials development both in academe and industry.

Accelerator Technologies Working Group

(includes tunneling, installation, utilities, communications, RF).

Foster dialog and partnerships with industry. Develop bases including costs for comparing different designs.

◆ Very Large Hadron Collider

● *The Snowmass-96 vlhc*

A 50 TeV x 50 TeV proton-proton collider
Luminosity _ 10^{34} $cm^{-2}s^{-1}$

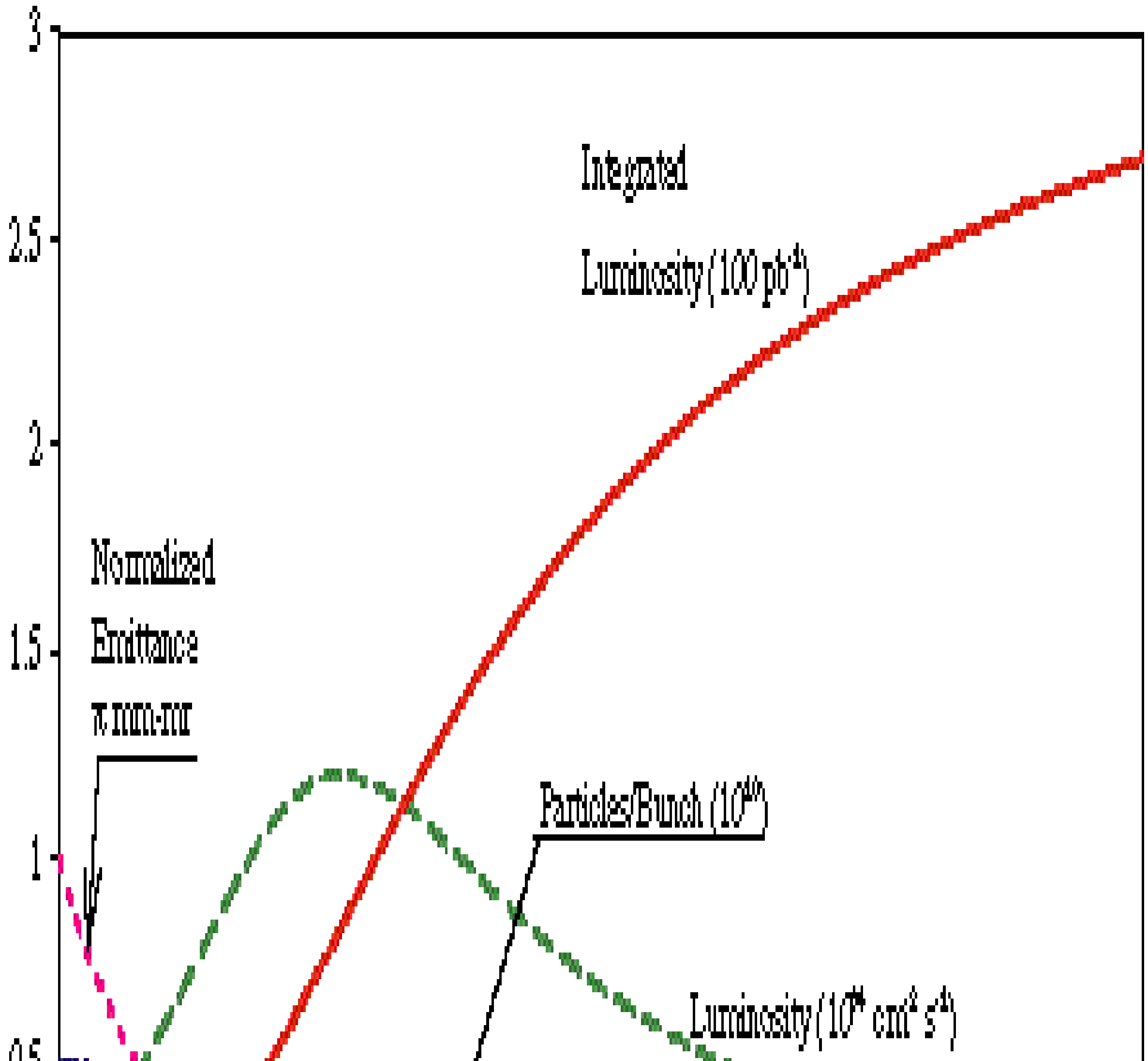
Magnet possibilities

◆ **Low field**	**B_2 T**
◆ **Moderate field**	**2 T_B_9 T**
◆ **High field**	**9 T_B_12 T**
◆ **Very high field**	**B_12 T**

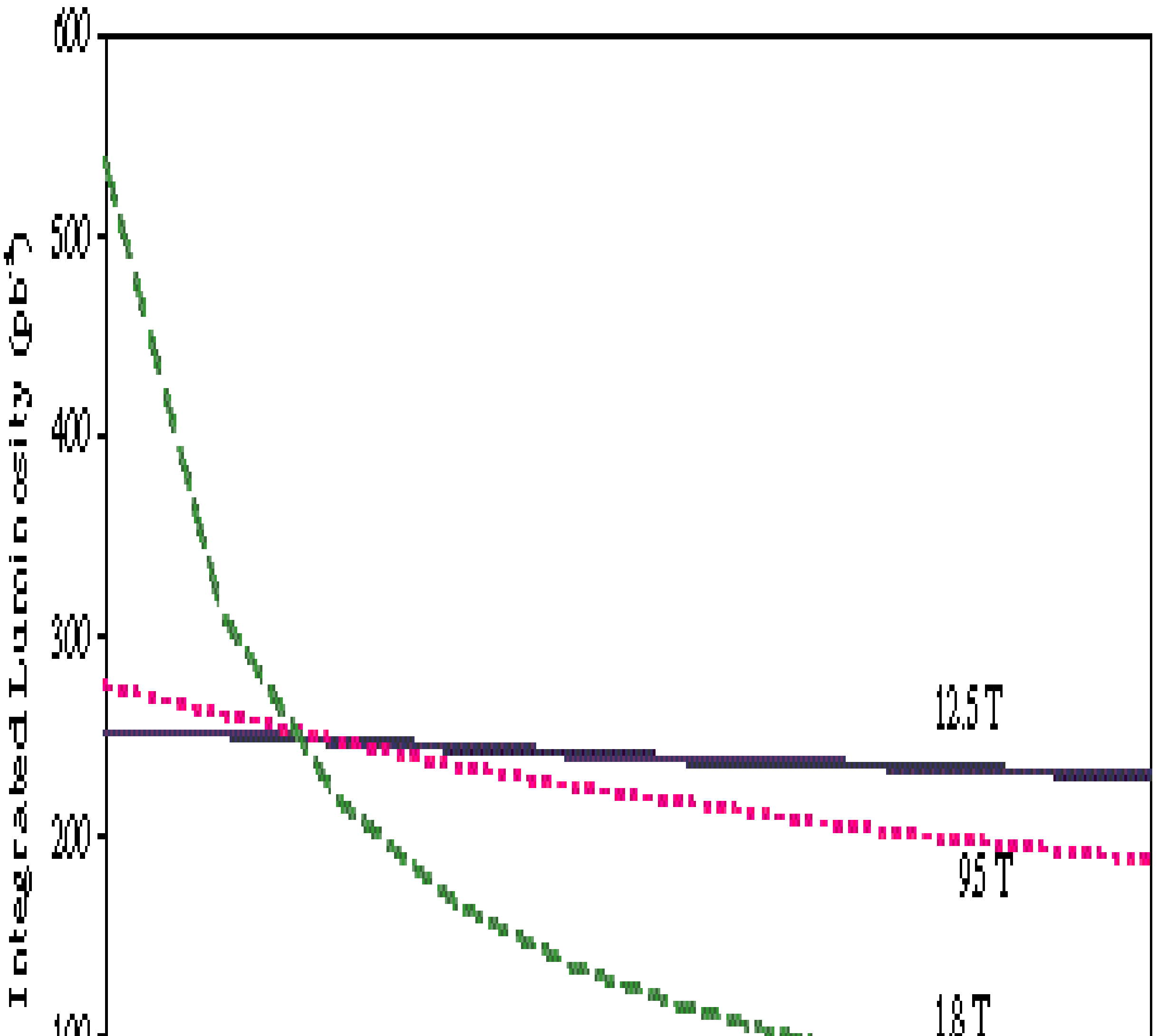
◆ Choosing the magnet strength

Options are distinguished by machine size, accelerator physics issues, superconducting material availability, magnet and R&D costs, and the amount of synchrotron radiation, and probably lots of other things.

- **Synchrotron radiation is bad: it puts power into the cryogenics.**
- **Synchrotron radiation is good: it makes the beam emittance (size) smaller.**


Integrated
Luminosity (100 pb-1)
Normalized
Emittance
π mm-mr
Particles/Bunch (10^10)
Luminosity (10^30 cm^-2 s^-1)

Beam parameters during a store for high-field (12.5 T) vlhc


Integrated Luminosity (pb-1)
600
500
400
300
200
100
12.5 T
9.5 T
1.8 T

Integrated luminosity of a store vs. initial rms emittance for vlhc options. A store is 20 hrs for the low-field case, 10 hrs for the others. Note that the integrated luminosity of the two high-field cases is almost independent of the initial emittance because of synchrotron radiation damping.

◆ *Magnet Options for vlhc*

Low-field magnets (B_2 T)

- **Uses superferric magnets**
  - **magnet is elegant and simple**
  - **the low-field collider may be cheaper**
  - (but not necessarily cheap)
- **There are some difficult machine questions**
  - **mostly related to the machine size**
  - **present design has very small aperture, requiring elegant feedback techniques**
- **No synchrotron radiation damping**

◆ *Magnet Options for vlhc*

● *Moderate-field magnets (2 T_B_9 T)*

Uses cos(q) NbTi magnets.

- **magnet and machine are well understood**
- **Fermilab is doing this R&D via LHC quadrupole program**

Little synch. radiation damping except at high end

- **the low-field collider may be cheaper**
- **needs expensive 1.8 K cryogenics for B_7 T**

◆ *Magnet Options for vlhc*

- ***High-field magnets (~9 T _ B _ 12 T)***
  - **lots of synchrotron radiation damping**
  - **accelerator physics issues are understood (?)**
  - **numerous design options for magnets**

Cos(q) NbTi at 1.8 K for B_10 T

Material is well understood, available and sort of cheap.
Require very high mechanical and material tolerances

Cos(q) NbTiTa at 1.8 K for B_11 T (?)

Require very high mechanical and material tolerances
SC material behavior is not understood

Cos(q) Nb_3Sn (Al?) at 4.5 K for B_12 T

Material needs improvement in Jc at high field
Difficult to handle, new to Fermilab
Material expensive now, needs cost-reducing R&D
Mechanical and material tolerances are relaxed
Nb3Al has much better strain resistance

Block designs Nb_3Sn (Al?) for B_? T

Requires more of the expensive SC material (hybrid possibilities)
May have simple assembly options

◆ *Magnet Options for vlhc*

- ***Very-high-field magnets (B _ 12 T)***
  - **oodles of synchrotron radiation damping**
  - **too much synchrotron radiation power!**
  - **limited design options for magnets**

Neither cos(q) nor NbTi are possible options

Might use block design Nb_3Sn (Al?) for B_? T

Requires a lot of the expensive SC material (hybrids less likely)
May have simple assembly options

HTS ?

Who knows?
Some interesting progress lately
Moderate effort seems worthwhile

◆ *Magnet R&D at Fermilab*

- ***Low-field superferric — Pipetron***
- ***Moderate-field — LHC quads***
  not actively working on a dipole
- ***High-field dipole***

  Three design options for 10 T – 11 T

  Cos(q) with NbTi (a la LHC) or NbTiTa
  Cos(q) 2-layer coil using Nb_3Sn (Al)
  Cos(q) 3-layer hybrid Nb_3Sn(Al) + NbTi

  - **Watching pancake coil designs (LBNL) carefully**
- ***Not working on very high-field designs***

◆ *High-field R&D at Fermilab?*

● *Two approaches to 10 T — 11 T dipoles*

- **Use NbTi or NbTiTa at the edge of its capability**
  - **Good and well understood mechanical properties**
  - **Techniques and tooling well known at Fermilab**
  - **"Inexpensive" material**
  - **Not much material R&D required**
  - **Tiny temperature margin**
  - **Requires exceptional engineering and QA**

- **Use Nb_3Sn or Nb_3Al comfortably within its capability**
  - **Poor and unpredictable mechanical properties**
  - **Techniques and tooling new at Fermilab**
  - **Expensive material**
  - **Significant material R&D required**
  - **Large temperature margin**
  - **Requires "clever" engineering for cost reduction**

Three-year plan for vlhc R&D

R&D goals for high-field vlhc *(B_{max} _ 11T)*

- **Year one (1998) design magnet, build infrastructure**
  - **Continue NbTiTa studies**
  - **Begin accelerator physics and accelerator systems studies via vlhc Steering Committee mechanism**
  - **Start engineering designs and tests for 11 T cos(q) dipoles**
  - **Procure some Nb_3Sn wire for prototype coils**
  - **Build infrastructure (ovens, SSTS) for Nb_3Sn work**
- **Year two assemble tooling, materials R&D**
  - **Initiate industrial R&D contracts for improved Nb_3Sn and Nb_3Al conductor**
  - **Procure tooling for Nb_3Sn 2-layer cos(q) design**
  - **Initiate 3-layer design**
  - **Decide about NbTiTa possibilities**
- **Year three build & test models, optimize design**
  - **Complete engineering designs for 11 T dipole using improved conductor.**
  - **Test one or more 11 T model (1-2 m) 2-layer cos(q) dipoles**
  - **Procure tooling and start material R&D for 3-layer design**

◆ Three-year plan for vlhc R&D

● *R&D goals for low-field vlhc* *(B_{max} _ 2T)*

- **Year one (1998) component R&D**
  - **Conductor development, NbTi and Nb_3Al**
  - **Begin accelerator physics and accelerator systems studies via vlhc Steering Committee mechanism**
  - **Invar cry-pipe tests**
  - **Cryo system and drive transformer for 50 m prototype**
  - **Steel pole tip design and test, incl. measurement system**
- **Year two 50 m magnet assembly in M-west**
  - **Assemble 50 m transmission line loop**
  - **Build and test 50 m magnet with drive transformer**
  - **Design Cryo system for string test**
  - **Design 100 kA power supply and current leads**
  - **Long magnet mechanical design**
- **Year three string test using 100 kA current leads**
  - **Continue long magnet mechanical design**
  - **Build a number of 50 m magnets**
  - **Assemble cryogenic and power systems for string test**
  - **Install and test magnet string with power leads**

◆ Three-year plan for vlhc R&D

● *R&D effort for high-field vlhc* *(B_{max} _ 11T)*

	FY98	FY99	FY00	
Personnel (H-F magnets)				
Physicists	2	4	5	
Engineers	3	5	7	
Des / Draft		1	3	5
Technicians + other	0.5	5	8	
Total personnel	**6.5**	**17**	**25**	
M&S (High-field magnets)	**$200 K**	**$525 K**	**$1100 K**	
M&S (superconductor R&D)	**175 K**	**500 K**	**1000 K**	**(grow to $2 M/yr)**
Total M&S (High-field + SC R&D)	**$375 K**	**$1025 K**	**$2100 K**	

◆ Three-year plan for vlhc R&D

● *R&D effort for low-field vlhc* (B_{max} _ 2T)

	FY98	FY99	FY00	
Personnel (L-F vlhc)				
Physicists	4.5	4.5	4.5	
Engineers	1.0	7	7	
Des / Draft		0.5	2.5	2.5
Technicians + other	1.5	10	16	
Total personnel	**7.5**	**24**	**30**	
Division distribution				
Beams Div.	3	12	16	
Technical Div.	3	8	11	
Other Divs.		1.5	4	3
M&S (Low-field vlhc)	**$350 K**	**$1500 K**	**$3000 K**	

◆ New and improved materials

● *Low-temperature superconductor*

- **Contracted with industry for improvements in binary (NbTi) at high field and 1.8 K. Attained 7% improvement in J_c.**
- **Collaborating in an SBIR with industry an universities on ternary (NbTiTa) LTS. Hoping for a better understanding of J_c and H_{c2} behavior, and better performance, particularly increased H_{c2}.**
- **Beginning a study of possibilities of fine-filament Nb_3Sn and Nb_3Al, to improve J_c at high field and to lower cost.**
  This will lead to a long-term R&D effort to improve and lower the cost of A-15 superconducting materials.
  (This becomes expensive in out years due to large-billet processing.)

New and improved materials

- ***High-temperature superconductor***
  - **Entering the field with HTS power leads.**
    6 kA lead for Tevatron successfully tested
    13 kA for LHC in less than 1 year
  - **Working with Cornell and BNL to procure and test some low-field HTS quadrupole coils.**
  - **Designing (with University of Wisconsin) a liquid neon test dewar.**
  - **Closely watching HTS cable R&D at LBNL. They have made and successfully tested a 1000 A Rutherford cable.**

- ***HTS payoff for magnets may be far away, but it's worth a try.***

◆ *Does HEP have a future?*

- ***Yes, but only through***

International collaboration

- ***We need to get serious: form a lab that is truly world-wide in scope.***

  CERN is an example, but not a model.

- ***Here are some possible steps:***

  - **LHC at CERN with small US and Japanese help (_ 5%) This is <u>already happening</u>.**
  - **NLC in Asia with big U.S. and/or European help (25% each)**

f vlhc R&D at Fermilab

- **vlhc in U.S. (Fermilab) with big European & Asian help**